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Using sewage sludge as an alternative fuel for the cement production process

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Abstract. One of the current challenges for wastewater treatment plant managers is how to find and implement new, sustainable solutions for sludge treatment and disposal. According to EU Directive 91/271/EEC, by 31 December 2018, Romania must enter into full compliance with the international regulations regarding wastewater treatment. This means that sludge production will greatly increase, together with a need for new, advanced technologies to address not only the disposal issue but also the need for energy efficient solutions. This paper presents two solutions for sludge treatment: a pilot installation for sludge treatment that entails drying, mixed biomass-sludge pelletizing and incineration in pellet boilers, developed by a team of Romanian experts; and using dried sludge as an alternative fuel for cement production, in the biggest cement factories in Romania. For these solutions, the key factor that influences both technologies are the drying process that, from an economic point of view, requires a high level of energy consumption. Despite this, considering the fact that, following the combustion process, the sludge volume is reduced and a significant amount of energy is recovered, these represent strong arguments to support the economic reliability of the technologies.

1. Introduction

As a result of the negotiation process in September 2015 at the UN Sustainable Development Summit, process that involved more than 193-member states of the United Nations, a great number of representatives of the civil society and many other stakeholder groups, the entire world was presented with a new and ambitious set of goals. These goals aimed to tackle a broad range of social and economic development issues: poverty, hunger, health, education, climate change, gender equality, water scarcity, sanitation, energy, the environment and social justice [1]. These 17 Sustainable Development Goals, also known as "Transforming our world: the 2030 Agenda for Sustainable Development", include a set of 169 targets, each with 1 to 3 indicators that are used to measure the global progress towards achieving each of these goals.

With water and sanitation at the very core of sustainable development, goal number 6: Clean Water and Sanitation sets clear targets aimed at ensuring the availability and sustainable management of water and sanitation for all. The third target of this goal addresses the need to improve water quality by reducing pollution, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. Progress in this direction will be quantified by two indicators: the proportion of bodies of water with good ambient water quality and the proportion of wastewater being

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safely treated. Although, during 2016 and 2017, progress was made in regards to the safety of the wastewater treatment processes, there remain countries that engage in the unsafe management of faecal waste and wastewater that continues to present a major risk to public health and the environment.

At the European level, efforts to improve the wastewater sector and wastewater treatment processes are regulated by EU 91/271/EEC Council Directive. The directive states that, by the end of 2018, all agglomerations with more than 2,000 PE must have a wastewater treatment plant in place [2].

2. Current issues and challenges in the Romanian wastewater sector

The ninth report on the implementation status and the programmes for implementing Council Directive 91/271/EEC concerning urban waste water treatment was published in 2017 and presents the latest data on legal compliance and 'distance to compliance' rates concerning the collection of wastewater, secondary treatment and the more stringent treatment of the wastewater by all EU member states.

When it comes to Romania, the data reveal a worrying situation. While, based on the previous report on the implementation status, the situation for each agglomeration could not be assessed, due to insufficient data, the results of the latest report indicate that, in 2014, the distance to compliance, including pending deadlines, represents 38% of the generated load concerning the connection, 64% of the connected load to the collecting systems for secondary treatment and 84% of the connected load to the collecting systems in agglomerations of over 10,000 PE for more stringent treatment. The projects scheduled for implementation in the following years are consistent with the need to comply with the Directive. However, the achievements are forecast to be reached between 2027-2030, far beyond the final deadlines of 2015 and 2018 [3].

It appears that Romania is underperforming in all three areas regarding compliance with the 91/271/EEC Directive, as shown in figure 1. This increases the demand and need for greater investment in the wastewater treatment sector.

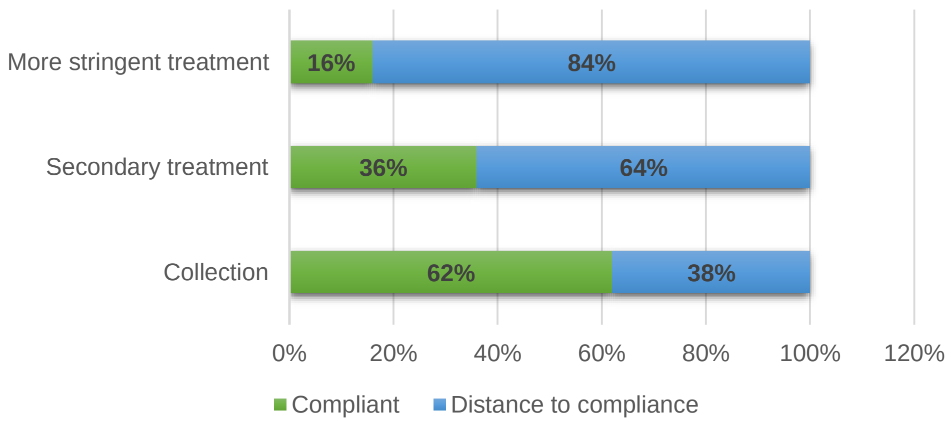

Figure 1. Romania – Distance to compliance with the 91/271/EEC Directive.

Investment in the wastewater sector will increase the total volume of water treated and therefore plant managers will be faced with a new, challenging issue: the treatment and disposal of the sludge resulting from the treatment process. The European Union classifies wastewater sludge as waste and sets clear regulations regarding the use and disposal of this by-product.

In Romania, in 2014, more than 75% of the sludge was disposed of through landfill or applied directly to agricultural land but considering the fact that sewage sludge represents a source of energy and nutrients, it is possible to use it as a raw material for industrial processes and energy production [4]. The 211/2011 Law (for the 2008/98/EC Directive) sets the deadline for reaching the 50% waste recycling target as 2020. Because there are large penalties for non-compliance with the deadline, it is assumed that the disposal sites operators will either reject the sludge or charge very high taxes, thereby ensuring that the disposal of sludge through landfill is significantly reduced or even ceases.

3. Sludge pelletizing and combustion in pellet boilers

In order to address the stringent need to develop new, innovative solutions for sludge management, a team of experts from the Medgreen Cluster was involved in a series of research activities focused on different scenarios for sludge incineration in order to reduce its volume and decrease the cost of processing it through energy recovery. Following a detailed analysis of the existing technology, the possibility of drying and pelletizing the sludge was tested.

This technology relies on the advanced drying of the dewatered sludge to a concentration of 80-90% of DS (established after a series of tests) then mixing it in different proportions with dry biomass (such as straw or sawdust), in order to increase its calorific value [5]. The samples for the first tests were collected from the Constanta Sud Wastewater Treatment Plant and the pelletizing test were conducted at the National Research and Development Institute for Machinery and Installations for Agriculture and Food Industry. The process proved very difficult, as the pelleting press was designed for wood biomass pelletizing. The high content of water in the sludge (51%) and absence of lignin resulted in low quality pellets. The results of the tests are shown below (figures 2-4).

Figure 2. Sludge and straw mix.

Figure 3. Sample 1. Pellets from sludge (20% sludge – 80% straw).

Figure 4. Sample 2. Pellets from sludge (30% sludge – 70% straw).

The second round of tests was conducted on samples collected from the same location. Prior to the pelletizing process, the sludge was analysed in order to determine its physicochemical properties and calorific value, both before and after the drying process. Results are shown in table 1.

Table 1. Higher calorific value and DS % of the sludge samples.

	HCV (kcal/kg)
Sample 1 (54.11% DS)	430
Sample 2 (72.9% DS)	2828

The dried sludge was tested, Germany, where at the Kahl Laboratory, approximately 100 kg of pellets were produced, using the 14-175 pelleting press shown in figure 5. The press is specially designed for laboratory tests, can be used for testing the pelleting qualities of a diverse range of products in order to obtain optimal mixes, and operates on the flat die principle.

In order to produce high quality pellets, the sludge had to be dried to a moisture content of around 5-10% and ground at about 0.5 mm as in the sample that can be seen in figure 6. The pellets that resulted are shown in figure 7.

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Figure 5. Pelleting press.

Figure 6. Sludge prepared for pelleting.

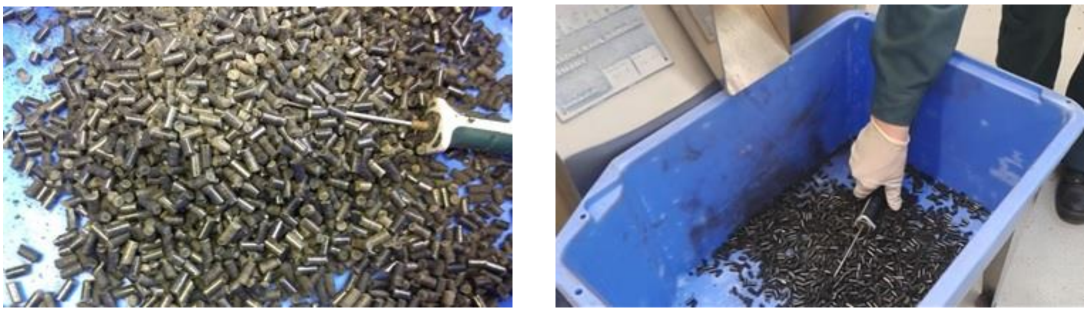

Figure 7. Sludge pellets.

The pellets produced were tested in order to determine the mass loss using the Thermogravimetric Analyzer Leco TGA701. Together with the sludge pellets, samples of sawdust and sunflower pellets were also analysed for comparison purposes. The results of the tests are shown below in the tables 2, 3, 4 and figures 8, 9, 10.

Table 2. Sample 1 parameters: Sludge pellets.

Name	Method	Location	Batch	Crucible Mass	Initial Mass	Moisture	Ash
Sludge pellets	Test	17	Batch#5	21.4319	1.0272	5.66	49.18

Table 3. Sample 2 parameters: Sunflower pellets.

Name	Method	Location	Batch	Crucible Mass	Initial Mass	Moisture	Ash
Sunflower pellets	Test	4	Batch#2	22.7869	1.0937	7.95	2.25

Table 4. Sample 3 parameters: Sawdust pellets.

Name	Method	Location	Batch	Crucible Mass	Initial Mass	Moisture	Ash
Sawdust pellets	Test	2	Batch#2	21.7064	1.0079	8.71	2.32

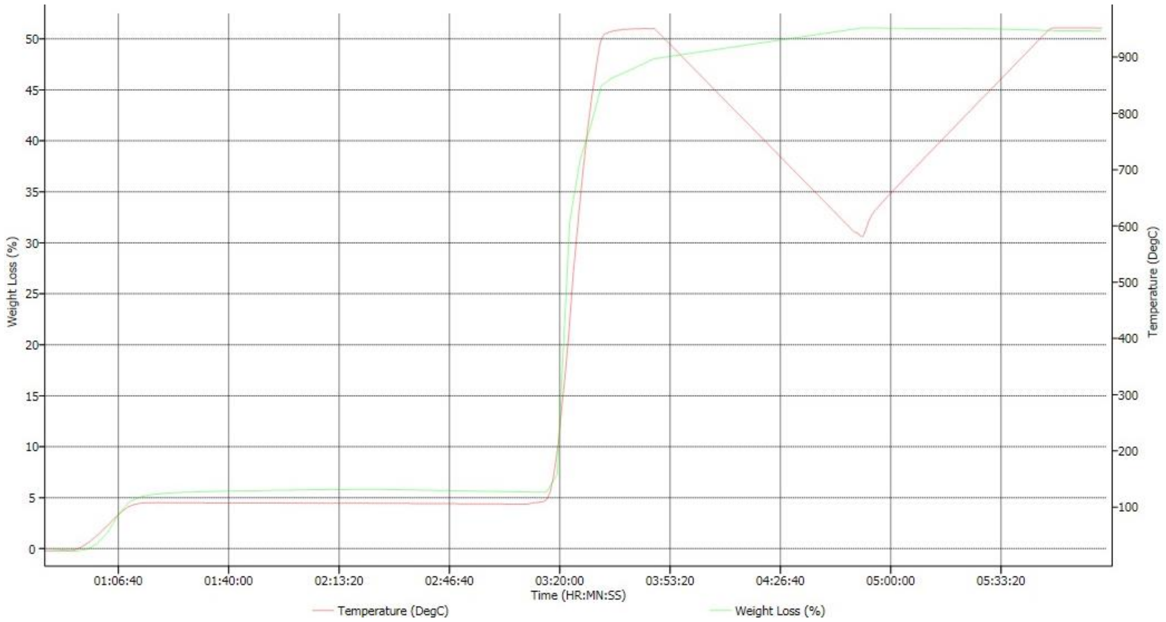

Figure 8. Weight-loss – sample 1: sludge pellets.

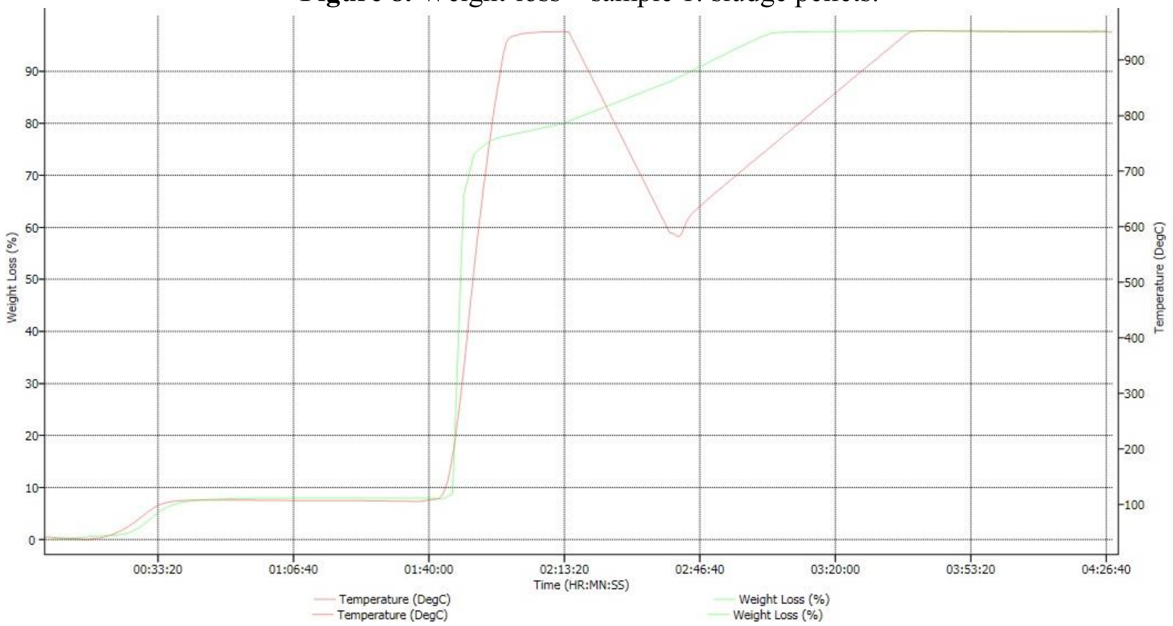

Figure 9. Weight-loss – sample 2: sunflower pellets.

Next, a first round of combustion tests was performed in an EcoHornet pellet boiler, for a mixture of sludge and sawdust pellets (figures 11, 12). This specific type of boiler was selected due to its high efficiency and combustion temperature (more than 1250°C). In order to determine the best solution, a comprehensive value analysis, based on the AHP (Analytical Hierarchy Processes) methodology, was conducted. The criteria considered when performing the analysis were: the temperature at which combustion occurs, the heat transfer, the exhaust gases, the fuelling system, the air supply system, the automation and control system, the manufacturing and maintenance process, and the production cost.

The tests will continue in order to determine if the boiler needs manufacturing adjustments for sludge incineration only and for further research regarding the efficiency of the process, measuring the exhaust gasses, and analysing the ash composition.

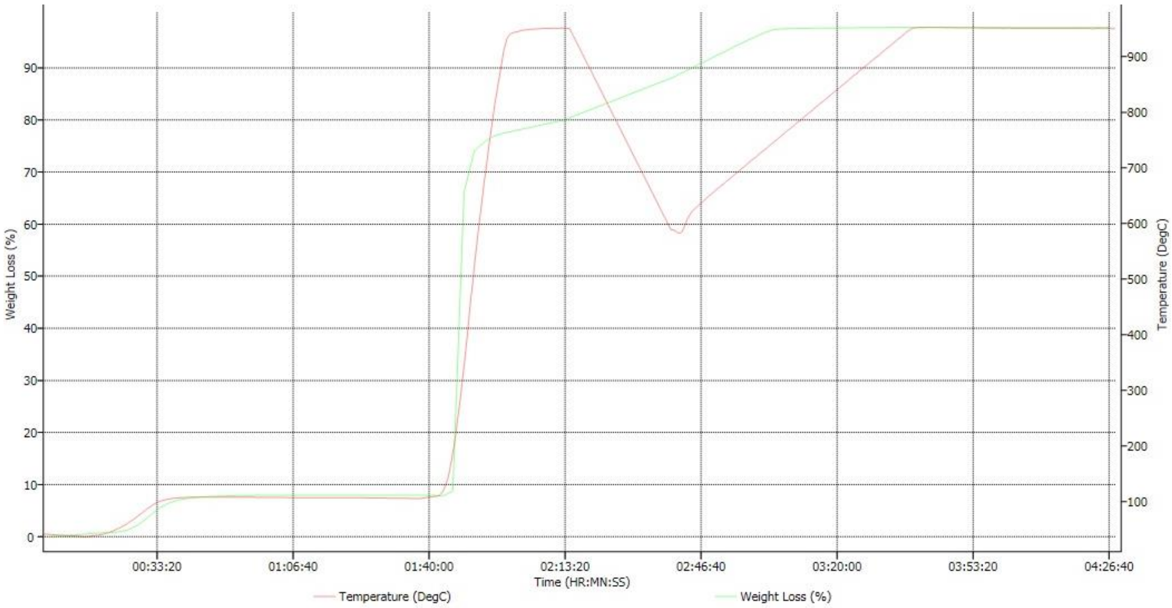

Figure 10. Weight-loss – sample 3: Sawdust pellets.

Figure 11. Mixture of sawdust and sludge pellets prepared for incineration.

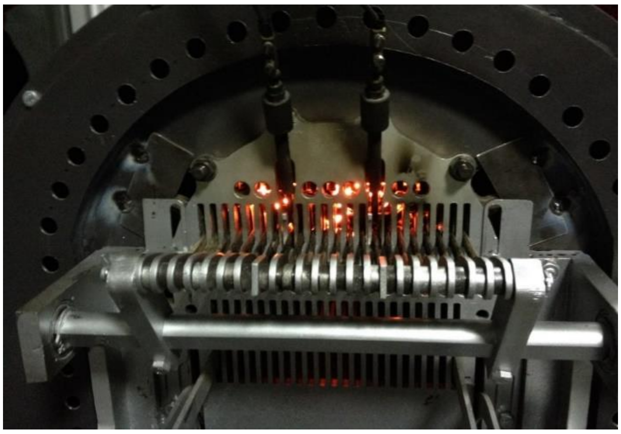

Figure 12. Incineration process.

4. Using dried sludge as an alternative fuel for the cement production process

Currently, in Romania, the only way for wastewater treatment plants managers to recover energy from sludge is via coprocessing in cement plants. All of the cement plants presented in table 5 are authorized to co-process waste and willing to accept sludge, but they require a gate fee in order to cover the additional operational costs, that depend on the degree of moisture in the sludge and its calorific value. However, the use of sewage sludge in cement kilns also offers benefits for cement producers, as it provides a substitute for conventional fuels and can result in decreased CO_2 emissions.

Taken into account the fact that all of the factories are located in strategic areas of the country, a solution to the sludge issue could be the processing of sludge from multiple wastewater plants at the cement plant location. In the future, the author's research will be directed towards developing a pilot system to be tested at one of the cement factories mentioned above. The activities conducted will include analysing the costs of collecting sludge from the surrounding wastewater treatment plants, introducing the drying process in the cement plant technological flow, and incinerating the sludge in the cement kilns.

Table 5. Cement plants in Romania.

Location	**County**	**Owner**
Bicaz	Neamt	HeidelbergCement
Medgidia	Constanta	LafargeHolcim
Fieni	Prahova	HeidelbergCement
Campulung	Arges	LafargeHolcim
Deva	Hunedoara	HeidelbergCement
Alesd	Bihor	LafargeHolcim
Hoghiz	Brasov	LafargeHolcim

5. Conclusion

Sludge management is a continuous, complex issue that needs to be addressed in both the short- and medium-term. There are a number of alternatives to the traditional landfilling disposal method, but further research needs to be conducted in order to determine the best solutions, tailored to each environment in which the wastewater treatment plant operates.

Research activities show that sludge incineration is not a simple process due to its high content of water and combustion parameters. However, the method offers a series of benefits, the most important of which is the volume and mass decrease. In order to convert sludge incineration into an energy recovery process, there is the need for complex solutions and in-depth analysis in order to guarantee the sustainability of the process.

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